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<p>(21) International Application Number: PCT/NL97/00398</p> <p>(22) International Filing Date: 8 July 1997 (08.07.97)</p> <p>(30) Priority Data: 1003538 8 July 1996 (08.07.96) NL</p> <p>(71) Applicant (for all designated States except US): ADVANCED SEMICONDUCTOR MATERIALS INTERNATIONAL N.V. [NL/NL]; Rembrandtlaan 9, NL-3723 BG Bilthoven (NL).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): GRANNEMAN, Emst, Hendrik, August [NL/NL]; Hoge Naarderweg 71A, NL-1217 AD Hilversum (NL). HUUSSEN, Frank [NL/NL]; Koppellaan 8, NL-3721 PE Bilthoven (NL).</p> <p>(74) Agent: DE BRUIJN, Leendert, C.; Nederlandsch Octrooibureau, Scheveningseweg 82, P.O. Box 29720, NL-2502 LS The Hague (NL).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report.</i> <i>In English translation (filed in Dutch).</i></p>
<p>(54) Title: METHOD AND APPARATUS FOR CONTACTLESS TREATMENT OF A SEMICONDUCTOR SUBSTRATE IN WAFER FORM</p>		
<p>(57) Abstract</p> <p>Such a treatment comprises heating the semiconductor substrate. To this end it is proposed to position the semiconductor substrate between two side sections of an enclosing apparatus and to keep the semiconductor substrate floating between said two side sections by introducing gas streams. It has been found that it is particularly effective to heat the substrate by means of at least one of said side sections. Using subject method and apparatus it is also possible to allow one of the gas streams to function as process gas, it being possible more particularly to supply process gas from one side section at a relatively low temperature to the semiconductor substrate, whilst the other side of the semiconductor substrate is subjected to a relatively high temperature originating from the opposite side section.</p>		

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Method and apparatus for contactless treatment of a semiconductor substrate in wafer form

5 The present invention relates to a method for contactless treatment of a semiconductor wafer substrate, comprising placing said substrate in an apparatus which at least partially encloses said substrate and applying two gas streams, in opposing directions, from first and second side sections
10 located opposite one another, to the two opposing sides of the semiconductor substrate.

 A method of this type is disclosed in Netherlands Laid Open Application 8402410, in which, furthermore, reference is made to Netherlands Laid Open Applications 8103979, 8200753 and
15 8203318.

 From these publications it is known to position a wafer such that it is floating between the two side sections. If the gas flow is suitably chosen, it has been found that a highly accurate definition of the position of the wafer with respect
20 to the side sections is possible and this position is relatively fixed, that is to say little variation occurs in the position of the wafer with respect to the side sections. In the patent publications concerned it is described that the wafer is subjected to a wet treatment and is then possibly dried. For
25 the purposes of drying, the gas which holds the wafer in place is heated to about 100 °C and is moved over the surface of the wafer, as a result of which the moisture present is automatically removed.

 Heating is frequently necessary when treating semiconductor
30 substrates. Heating can involve annealing or raising the temperature to make deposition or other processes possible. In the prior art wafers are to this end placed in furnaces and then heated. Although this method is adequate, it has at least two disadvantages. Firstly, a method of this type is never
35 contactless, that is to say certain points of the wafer must always be supported. Secondly, it takes a relatively long time to heat a wafer. This is due not so much to the thermal capacity of the wafer itself as to the thermal capacity of the

furnace in which the wafers are placed.

In order to solve this problem single wafer systems have been disclosed with which rapid heating was achieved with the aid of high power lamps (50-80 kW). Such a method is particularly expensive and difficult to control.

US patent 4 622 918 discloses an apparatus wherein a wafer is fed through between a number of columns located some distance apart. Sets of columns located opposite one another, between which the wafer moves, are likewise some distance apart. In the gap between the sets of columns, heating is effected by means of a lamp some distance away. This apparatus also has the drawback of relatively slow energy-consuming heating by means of lamps.

It has been found that only limited heating can take place effectively by heating the gases, as is described in the abovementioned Netherlands applications.

The aim of the present invention is to provide a method with which contactless heating of semiconductor substrates to relatively high temperature within a relatively short time is possible.

This aim is achieved with an apparatus as described above in that the spacing between each of said first and second side sections and the semiconductor substrate is set to at most 1.0 mm and at least one of said side sections is heated to a temperature higher than 200 °C.

Surprisingly, it has been found that if the spacing between the side sections, or between side section and wafer, is set to be relatively small, particularly rapid heat transfer can take place. It is possible to achieve heating to far above 1000 °C within a few seconds. Because with this arrangement the wafer, in principle, does not have to be supported, but is held accurately and definitively in its place by the gas streams, the wafer will also not be subjected to stresses generated by local temperature differences and distortion will be prevented as far as possible. Incidentally, it is pointed out that if a slight degree of distortion does take place, the stabilising effect of the gas streams in opposing directions is such that the wafer is pressed straight in a 'gentle' manner without

damage.

Furthermore, it has been found that, relatively, particularly little energy is needed to achieve such heating of wafers. It will be understood that the method described above
5 is outstandingly suitable for processes in which wafers are treated one by one ('single wafer processing'). However, it is also possible to treat large numbers of wafers one after the other or parallel to one another in the manner described above.

Introduction of the wafer into the enclosing apparatus
10 described above can be effected in any way known from the prior art. A particularly simple method is that in which the side sections can be moved apart. The wafer can be placed between the side sections when the latter have been moved apart. Supporting means can optionally be present to fix the wafer in
15 such a position. The side sections then move towards one another and the function of the supporting means can be taken over by the gas stream moving out of the side sections concerned. As a result, the wafer moves away from the supporting means.

20 Apart from heating the semiconductor substrate in this way it is also possible to carry out treatments on the substrate, such as oxidation, etching or the deposition of layers. To this end it is possible to mix a gaseous medium with the gas which holds the wafer in its place. Of course, it is also possible to
25 position the wafer using process gas only. This is in contrast to what is described and suggested in the abovementioned Netherlands Applications, where only wet treatment of the related substrate takes place. This process gas can be supplied, uniformly distributed, from one of the side sections,
30 such that a uniform distribution over the related wafer surface takes place.

One of the problems encountered in the prior art when supplying process gas at elevated temperature and more particularly when depositing layers is that the apparatus used
35 to supply the process gas becomes contaminated by deposition of the material concerned from the process gas. This means that apparatus of this type have to be cleaned regularly and that major problems arise with regard to clogging.

With the method according to the invention it is possible to prevent these problems. This is because, according to a further embodiment of this method, a temperature difference is applied over the wafer. One of the side sections is heated to a relatively high temperature, whilst the other of the side sections is heated to a relatively low temperature. It has been found that, as a result of the thermal behaviour of the enclosing apparatus, the wafer will assume a temperature which is dependent on the position of the wafer with respect to the two heated side sections. If the two side sections are equidistant from the wafer and the same gas is present on both sides, the temperature will fairly accurately be the average of the values of the temperatures of each of the side sections.

If, by controlling one or both gas streams, the wafer is not located centrally between the two side sections, the temperature will change correspondingly.

If different types of gas are used, that is to say gases having different thermal conduction properties, a change in temperature will likewise take place. For example, when argon is used on one side and hydrogen is used on the other side it has been found that transfer between the relevant side section and the wafer is ten times better on the side where hydrogen is supplied.

Consequently, by means of a suitable choice of the temperatures concerned, it is possible to provide the side section from which the process gas is emitted with a temperature such that no deposition takes place on such side section, whilst the wafer is at a temperature which is so much higher that deposition does take place on such wafer.

It has been found that the rate of deposition of, for example, polysilicon from silane on a substrate is lower by a factor of 350 at 700 K and a partial pressure of 0.4 torr than at 900 K. This means that by controlling the temperature, deposition is negligible on the side section from which the process gas is supplied and which is at low temperature.

With this arrangement it is possible, in the starting position, to place the wafer with the 'device side' of the wafer towards the side section which is at the lowest

temperature, through which side section the process gas is subsequently supplied. As a result of supplying the reactive gases, the wafer is moved towards the side section at the higher temperature and, on assuming the higher temperature, deposition accordingly takes place. The reverse set-up is also possible. That is to say, the side section from which the gas emanates is at a higher temperature than the opposite side section. In this case the 'device side' of the wafer faces the side section which is at the lower temperature and the Bernoulli principle can be used by allowing the correct gas stream to flow against the top of the wafer. With this arrangement a reduced pressure is created beneath the wafer, which reduced pressure ensures that the wafer will float (in a stable manner) beneath the top side section. The hot (bottom) side section is then raised until the process situation is achieved.

It has been found that appreciable temperature differences between the related side section and the wafer are possible using the construction described above. A value of at least 150 °C and more particularly 200 °C may be mentioned by way of example.

With the method according to the invention, these values can be set very accurately. After all, it has been found that these values are mainly dependent on the position of the wafer in the enclosing apparatus. As already indicated above, the position of the wafer in the tunnel-like apparatus is accurately related to the quantity and type of gas supplied from the related side sections.

The invention also relates to an apparatus with which the above method can be carried out in all its alternative embodiments. In this apparatus at least one of the side sections is provided with heating means for heating said section(s) to above 250 °C. Surprisingly, it has been found that relatively little power is needed to achieve a relatively high temperature. It is in particular the thermal capacity of the side section concerned which is of importance for the stability of the process. The thermal capacity must be as high as possible.

The related side section can be provided with a number of spaced gas feed channels in order to provide uniform metering of the gas and more particularly process gas.

In a simple embodiment which is particularly suitable for deposition purposes, a very large number of injection points must be present. A construction of this type can, for example, be achieved by providing porous plates.

The invention will be explained below with reference to an illustrative embodiment shown in the drawing. In the drawing:
10 Fig. 1 shows, diagrammatically, an apparatus according to the invention in the position in which the semiconductor substrate is introduced;

Fig. 2 shows part of the apparatus after introduction of the semiconductor substrate; and

15 Fig. 3 shows a graph in which the rate of heating of the semiconductor substrate is shown for the apparatus according to Figs 1 and 2.

In Fig. 1 the apparatus according to the invention is indicated in its entirety by 1. This apparatus is provided with an inlet 4, which can be connected, in a manner not shown in more detail, to a 'load lock' or a cluster system for further treatment of semiconductor substrates.

The actual apparatus according to the invention, consisting of the first and second side sections 6 and 7, respectively, is
25 accommodated in a pressure vessel 2 for carrying out a process in a specific environment or under elevated or reduced pressure.

The first side section 6 is joined rigidly to the pressure vessel 2. A heating coil 8, which is connected to a control 5, is mounted inside said first side section. A gas supply line 12
30 is also present, which gas supply line is connected to the gas feeds 10 which consist of a number of uniformly distributed passages.

It must be understood that in practice a very much larger
35 number of passages will generally be used, which passages are each very much smaller than is shown. For the sake of clarity, the various features have been shown in exaggerated form in the drawing.

Side section 6 is provided at the ends with centring chamfers 13. As can be seen from Fig. 2, these serve for enclosure of a semiconductor substrate or wafer 3.

Second side section 7 is constructed correspondingly.
5 Supporting pins 11 for supporting the semiconductor substrate extend through the second side section 7.

As can be seen from Fig. 2, the various features are so dimensioned that when the two side sections are in the closed position, that is to say in the position in which said sections
10 are typically located 0.05 to 1 mm apart, the semiconductor substrate 3 is no longer supported by the supporting pins 11 but by the gas streams which move towards the semiconductor substrate 3 from both side sections.

It will be understood that the various features are
15 dependent on the application concerned.

Gas passages 10 in the second side section 7 are connected to a gas supply line 14, which is connected to a source 15.

The apparatus described above functions as follows:

Starting from the situation shown in Fig. 1, the wafer 3 is
20 placed on the supporting pins 11, as is also shown in Fig. 2. The second side section 7 is then moved up and the situation as shown in Fig. 2 is obtained. The wafer 3 is accurately positioned in the centre between the two side sections 6 and 7 by the gas streams issuing from the passages 10 in said two
25 side sections. Deviation in the position is possible by means of adjusting the gas flow.

The side sections are heated by operation of the heating elements 8 and 9 and it has been found that this heat is transferred to the wafer with negligible loss. In practice, it
30 has been found that almost immediately after it has entered the gap between the side sections 6 and 7 the wafer assumes the temperature thereof. This is in a situation where the temperature of the side sections 6 and 7 is identical. Such an example is shown in Fig. 3. In this case both side sections
35 have been heated to a temperature of approximately 1200 °C. It has been found that wafer 3 has the same temperature within four seconds. Because wafer 3 is not supported and is heated uniformly, no thermal stresses will be produced, as a result of

which there is no question of distortion.

At such an elevated temperature it is possible to anneal the wafer or to carry out an oxidising or reducing treatment. In the latter case the relevant gases are supplied as process
5 gases through the passages 10.

Apart from furnaces, radiation lamps are also used in the prior art, the wafer being positioned on a bearing surface. Apart from the abovementioned risk of distortion as a result of non-uniform heating caused by removal of heat to the support
10 point, the heating rate is relatively slow. Values of 5-10°/s are not uncommon if the wafer is on a susceptor. In all other cases, values of 50-100°/s have been found.

In certain cases it is, however, desirable to subject the wafer to a deposition treatment. The case in which a process
15 gas, from which material has to deposit on the wafer, is present in source 15 is chosen as an example here. To prevent the passages 10 in the second side section 7 from becoming clogged by premature deposition of material from the process gas concerned, it is proposed to bring the first side section
20 6 to a relatively high temperature and the second side section 7 to a relatively low temperature with the aid of control 5.

If, for example, for polysilicon the deposition temperature of material from the silane gas issuing from source 15 is 625 °C (900 K), it is proposed to heat the first side section 6 to
25 a temperature of 1100 K and the second side section 7 to a temperature of approximately 700 K. At 700 K virtually no deposition of material from the gas will take place, so that the passages 10 concerned will not clog. However, the wafer is found accurately to assume a temperature which is midway
30 between that of the first side section 6 and that of the second side section 7, this being the desired temperature of 900 K. As a result of the flow of the gases shown (Fig. 2), it is largely precluded that gas issuing from the second side section 7 will enter the first hot side section 6 and deposit there. In any
35 event it has not been found that passages 10 in the first side section 6 clog.

In the case of a deposition treatment of this type it is not uncommon first to supply an inert gas and then to supply

the treatment gas. This is represented symbolically by showing a number of gas bottles at 15 and the quantity or mixing ratio or type of gas supplied to the line 12 or 14 can be controlled by means of control means, which are not shown in more detail.

5 Close to the end sections of the side sections, the upper side section is provided with a large number of gas passages, whilst this is not the case for side section 7. In this way an accurately controlled gas purge flowing radially outwards can be provided and deposition on section 6 prevented.

10 If the side section 7 is at a lower temperature, it is not necessary to use the pins described above. The wafer can be placed directly on side section 7. In such a case it is not even desirable to use pins, because in a set-up of this type the 'device side' faces downwards.

15 It has been found that a very small amount of gas is needed with the method described above. An amount of between 0.1 and 25 litres per second under standard conditions under a pressure in the vessel which is between 1 torr and 1 atm may be mentioned here as an example. The various aspects are wholly
20 dependent on the process conditions.

When the treatment is complete, the side sections can be moved away from one another again and the wafer removed. Cooling takes place equally as rapidly as heating without any damage over the entire extent of the wafer.

25 It must be understood that the relative sizes shown in the figures are incorrect and have been introduced for the sake of clarity. Thus, the diameter of a typical wafer is approximately 6-8 inch and the thickness approximately 0.7 mm. The distance between a wafer and the surface of the relevant side sections
30 from which gases issue is of the order of magnitude of one or a few tenths of millimetres.

It is possible to impose a rotary movement on the wafer, as a result of which an even more uniform treatment is provided.

Such a rotation can, for example, be achieved by
35 positioning one or more of the channels 10 at an angle with respect to the vertical, as a result of which a spiral gas flow is generated.

These and further variants are obvious to a person skilled

in the art after reading the above description and fall within the scope of the appended claims.

Claims

1. Method for contactless treatment of a semiconductor wafer substrate comprising placing said substrate in an apparatus which at least partially encloses said substrate and applying two gas streams, in opposing directions, from first and second side sections located opposite one another, to the two opposing sides of the semiconductor substrate, characterised in that the spacing between each of said first and second side sections and the semiconductor substrate is set to at most 2 mm and at least one of said side sections is heated to a temperature higher than 200 °C.
2. Method according to Claim 1, wherein said side sections are movable with respect to one another, the semiconductor substrate is introduced at a relatively low temperature between the two side sections positioned a relatively large distance apart, after which the side sections are moved towards one another.
3. Method according to Claim 2, wherein in the starting position the substrate is supported by mechanical auxiliary means.
4. Method according to one of the preceding claims, wherein the substrate is subjected to a rotary movement.
5. Method according to one of the preceding claims, wherein at least one of said gas streams comprises a process gas.
6. Method according to Claim 5, wherein the first side section of the enclosing apparatus is brought to a first temperature and the second side section, which is opposite said first side section, is brought to a second lower temperature and in that the process gas is supplied from the second side section.
7. Method according to Claim 6, wherein the temperature difference between the first and second side sections is set to at least 150 °C.
8. Method according to Claim 7, wherein the temperature difference between the first and second side sections is set to at least 200 °C.
9. Method according to one of the preceding claims, in

combination with Claim 5, wherein the process gas is supplied such that it is uniformly distributed over the surface of the semiconductor substrate to be treated.

10. Method according to one of Claims 6-9, wherein the
5 substrate is moved from the mid point between the side sections by controlling the flow of gases.

11. Method according to one of Claims 6-10, wherein gases having different heat transfer are used from the first side section and from the second side section.

10 12. Apparatus (1) for contactless treatment of a semiconductor wafer substrate (3), comprising an enclosing part provided with at least first and second side sections (6, 7) for accommodating a semiconductor substrate (3) between them, characterised in that the gap between said first and second
15 side sections is at most 2 mm and preferably 0.1 to 1 mm and in that at least one of said side sections is provided with heating means (8, 9) for heating said section(s) to above 250 °C.

13. Apparatus according to Claim 12, wherein said side
20 sections are movable with respect to one another.

14. Apparatus according to Claim 12 or 13, wherein support means (11) are present which are effective when said side sections are in the position in which they have been brought outward.

25 15. Apparatus according to one of Claims 12-14, wherein at least one of said side sections is provided with a number of gas feed channels (10) arranged distributed over the length of said side section(s).

16. Apparatus according to Claim 15, wherein the number of
30 gas feed channels comprises a porous plate.

1/2

fig-1

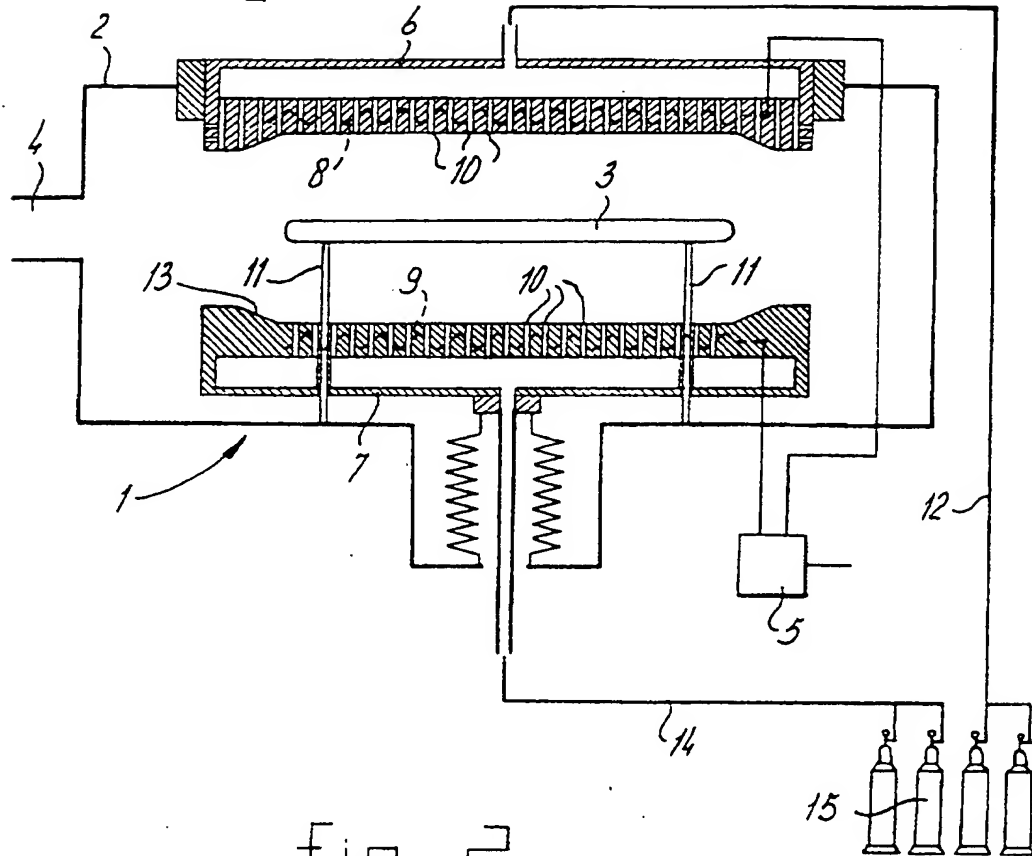


fig-2

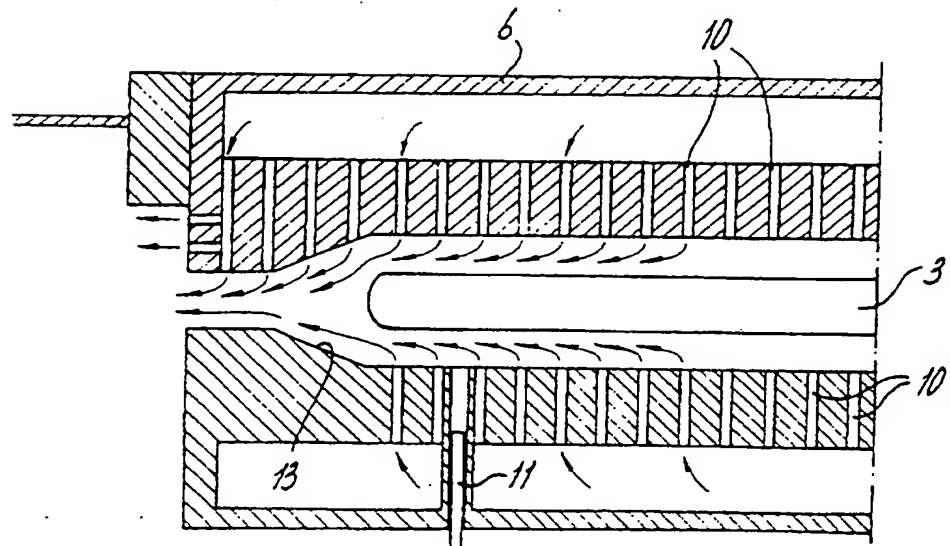
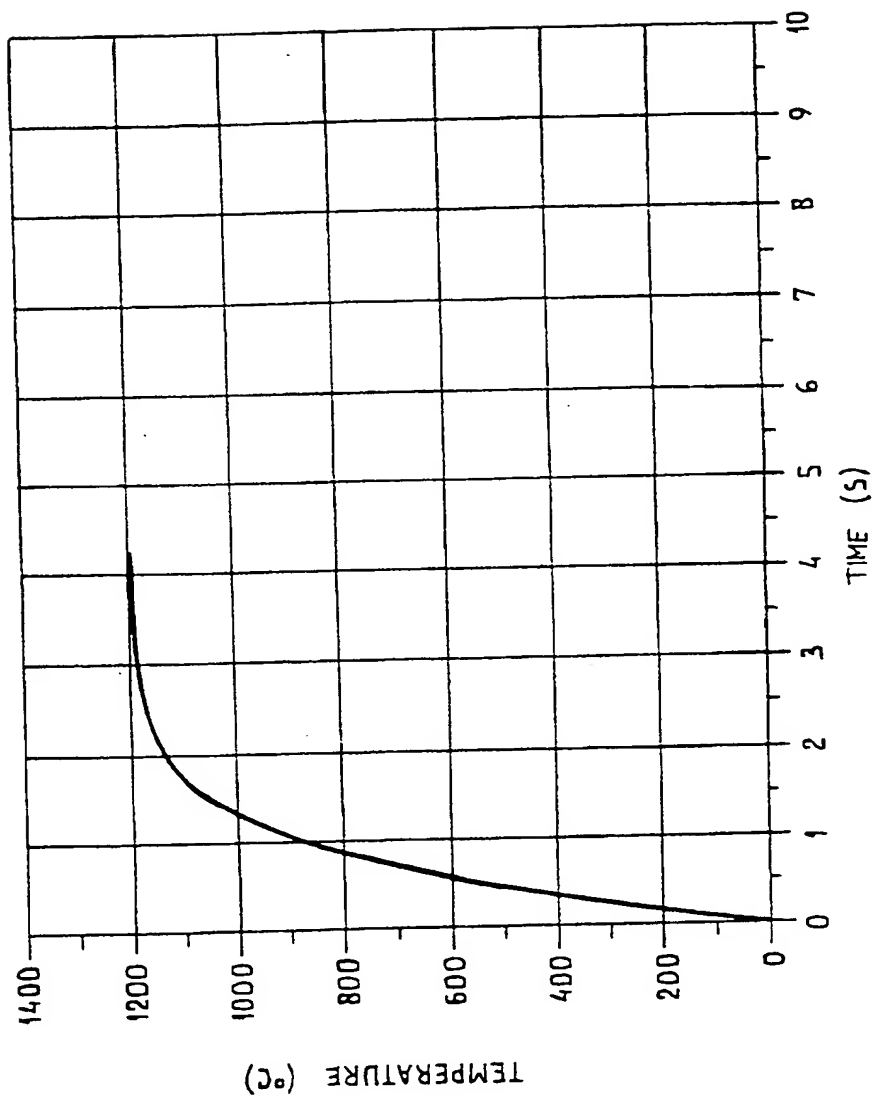


fig-3



INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 622 918 A (BOK) 18 November 1986 see column 1, line 15 - column 3, line 50; figures 1-14	1,5,9, 12,15,16
A	US 4 958 061 A (WAKABAYASHI) 18 September 1990 see column 4, line 53 - column 4, line 56; figure 1	1,3,12
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 85 (E-308), 13 April 1985 & JP 59 215718 A (KOKUSAI DENKI KK), 5 December 1984, see abstract	1,4,12, 15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4622918 A	18-11-86	NONE	
US 4958061 A	18-09-90	JP 2077119 A	16-03-90